Sure Footed
Development of an Innovative Walking System to Enable Early Gait Training

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Each year more than 1 million people in the U.S. will either have a stroke or be hospitalized for a traumatic brain injury, which often results in motor and sensory deficits that impact one's ability to ambulate.[1]Regardless of a patient's diagnosis, the common thread among all patients is their desire to walk again.

Research with acute stroke patients shows that early interventions that are of high intensity are strongly correlated with gains in walking ability and function.[2,3] The problem is that even when patients are medically stable, intense interventions are either too difficult or unsafe for both the patient and therapist.

Alternative Body Weight Support Systems

Over the last decade, engineers have developed different systems to assist therapists to safely train patients to stand and walk. The Lokomat and LiteGait are two of the more well-known systems. The Lokomat is a robotic body weight support (BWS) system that moves a patient's legs through a set gait pattern while walking over a treadmill[4] (Colombo et al, 2000). The LiteGait is a less costly system that allows an individual to walk either over-ground or over a treadmill with static body weight support.

Both of these systems have their limitations. The Lokomat requires a patient to train on a treadmill, and limits the patient's pelvic and trunk rotation and ability to use their arms.

In a study by Neckel et al involving stroke patients, it was found that patients generated forces against the robotic legs that indicated more typical CVA gait deviations, although the steps appeared "normal" within the robotic legs.[5]

In a study by Hidler et al that compared conventional gait training to the Lokomat in subacute stroke subjects, those individuals receiving conventional gait therapy made significantly greater gains in endurance and walking speed when compared to the Lokomat trained subjects.[6]

One aspect of motor learning is detecting error and problem solving solutions. Variable practice allows us to adapt and generalize our learning. With conventional gait training, there is natural variation with stepping as one negotiates the environment, as well as the demand to maintain postural control while stepping.

Constraining the legs within the robot and walking on the treadmill may not permit this variable, unguided practice; i.e., trial and error learning. The LiteGait allows the patient to walk over ground but does not provide a dynamic unloading system. This restricts patients since they cannot practice important balance activities that involve large ranges of motion (e.g., sit-to-stand, getting off the floor) and it impacts how the patient walks over ground. It also requires the patient or therapist to guide the metal unloading frame while the patient is walking. This is challenging for the therapist, particularly with lower-functioning patients.

Unique Weight Support System

Due to these limitations and others, Joe Hidler, PhD, of the National Rehabilitation Hospital (NRH) in Washington, DC, led a team of engineers and therapists to develop a more dynamic and interactive system. What resulted is now the commercially available gait and balance training system called ZeroG®.

The ZeroG is an overground body-weight support system that allows the therapist to challenge patients in a safe, controlled environment. The system allows patients to perform a variety of activities under partial weight support, such as walking with or without an assistive device, stepping over obstacles, walking on compliant surfaces, performing high-level balance activities (e.g., single limb stance, braiding the lower extremities, tandem stance) and practicing sit-to-stand from any surface, including the floor.

The ZeroG has three main features: the trolley, the unloading system, and the software system. Through a computer interface, the therapist controls the walking speed of the subject by adjusting the trolley tracking speed, how much unloading or body weight support to provide the patient, and how much the patient will be allowed to fall before the system catches.

The system has two modes: an overground walking mode and a balance training mode. The overground walking mode lets a patient practice walking at different speeds and levels body weight support. For safety reasons, while in this mode, the system will only allow the patient to fall up to six inches before catching. The other mode of ZeroG is the balance mode. The system allows the patient the opportunity to practice multiple balance techniques, exercises and recovery strategies without the fear of falling and hurting themselves.

Since many of these activities require the ability to move through a greater vertical range, the fall distance has greater flexibility in this mode. It can be disabled to permit practice of floor-to-standing transfers. The body weight support can also be set higher during these more risky activities to provide greater support and assistance, or can be decreased to make the task more challenging.

The system also records important performance measures that allow therapists to track a patient's improvement in walking ability and function. This includes recording the distance walked, how long the session lasted, the minimal and maximal body weight support provided, and the number of falls prevented during a session. This information can be exported to an Excel spreadsheet in summary form and/or bar graphs, which can then be used as supporting documentation in a patient's chart.

Case Study

Dennis is a 56-year-old male with history of hypertension who suffered a right pontine stroke in late February 2010. After spending 10 days in an acute care hospital, Dennis was transferred to the NRH for inpatient rehabilitation. Prior to the stroke, Dennis was completely independent and was working full-time as an elevator repairman.

On the initial evaluation, Dennis demonstrated 0-2/5 strength in the left lower limb and upper limb, with greater proximal than distal movement. He showed diminished tactile and proprioceptive sensation on the left. He was unable to stabilize his trunk adequately for limb movement in sitting or perform controlled, symmetrical weight shifts in any plane.

Dennis was able to take steps in the parallel bars with moderate to maximal assistance to advance the left leg and to maintain left knee extension in stance phase. Fortunately, the right side did not exhibit motor or sensory deficits. He said that after his stroke, he had tremendous weakness in his left arm and leg, and wondered if he would ever walk again.

Within a few days after admission, it was determined that Dennis would be a great candidate for a pilot study with the ZeroG. He was medically stable, demonstrated a hemiparesis, was able to follow commands and was within 30 days of having his CVA. He was also extremely motivated and willing to work hard to get well. These were the main inclusion criteria to be entered into the pilot study.

During his inpatient stay, Dennis received regular physical therapy sessions focused on improving the strength and motor control in his left arm and leg, as well as trunk musculature, standing balance training, postural control in standing, maintaining ROM and flexibility, endurance training, gait training with SBQC and SPC over even and uneven surfaces, family training and wheelchair use.

By participating in the ZeroG pilot study, Dennis received an additional 10 one-hour sessions of physical therapy in the ZeroG. "When Diane, my PT, strapped me into the harness of the ZeroG, little did I know I was on my way to walking," he reported. "My first steps were wobbly, but with the trust that I was gaining in the ZeroG knowing that it wouldn't let me fall no matter how wobbly my steps were, it gave me a new-found confidence in myself and confidence to try harder."

Set-up in the ZeroG and rest breaks with vital sign monitoring typically accounted for 20 to 25 minutes of the session. The remaining time was primarily spent ambulating, but also performing standing activities to build increased motor control of the left side and balance.

"With my PT telling me what to look out for with my steps, I was soon walking with an orderly gait," said Dennis. "Because the ZeroG has weight-bearing control, I was able to ask my PT to control it so I could push myself and walk at a comfortable level where I felt the strongest."

At discharge, after 25 days in rehab, Dennis still required close guarding to close supervision with his ambulation. Given his initial degree of impairment, he showed significant improvement in his gait speed, distance he could walk on his own, balance and the amount of assistance required to ambulate safely over different types of terrain.

Dennis' potential to ambulate was determined by the location and severity of the stroke. To optimize that potential, he was fortunate that he began therapy early in a structured program with an experienced, multidisciplinary team. He had excellent support from his family, and a positive, outgoing perspective toward life. These are all things that have been shown to optimize outcomes (see table for Dennis's changes from admission to discharge.)

Functional Improvements of a Stroke Patient After Gait Training		
Outcome Measures	**Admission**	**Discharge**
Trunk Impairment Scale	13/23	18/23
Modified Ashworth	all scores = 0 except following:	all scores = 0 except following:
UE elbow flexion	2	2
elbow extension	0	2
wrist extension	0	2
LE ankle dorsiflexion	0	2
Fugl-Meyer		
UE	21/66	41/66
LE	17/34	23/34
Berg Balance Scale	24/56	40/56
5 Meter Walk	.171 m/sec w/mod A and RW	.421 m/sec w/CGA and SBQC
Functional Ambulation Category	2	3
6 Minute Walk	200 ft. w/mod A and RW	547 ft. w/CGA and SBQC
CES-D	2	3

Dennis also had early access to the ZeroG. The ZeroG permitted intense, task-specific training of gait soon after his injury without the fear of falling. It is likely that the ZeroG played a big part in the recovery of his walking. In his experience with the ZeroG and the tremendous progress that he made, Dennis gained the knowledge and confidence that he would one day walk independently.

References

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